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CYCLES OF EROSION IN THE PIEDMONT PROVINCE OF PENNSYLVANIA¹

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Since 1912, when Professor Barrell brought to the attention of the Geological Society of America some conclusions opposed to the earlier interpretation of the erosion history of certain portions of the Appalachian highlands, the writer has had in mind the possible application of similar conclusions to the erosion history of the Piedmont province of Pennsylvania. The results of this intention are presented in this paper. The conclusions reached are not precisely in accord with those enforced with so much originality by Professor Barrell, nor do they involve much that is new in the interpretation of the erosion history of eastern Pennsylvania, but they are presented as a record of the present stage of the study of the peneplains of the Piedmont province of Pennsylvania.

It is the purpose of the paper to call attention to the fact that the erosion history of eastern Pennsylvania as indicated by altitudes and by the record of sedimentation must have been complex, that it was made up not of one or two or three cycles of prolonged erosion, but of many interrupted cycles, and that vestiges of nine of these cycles testify to their reality. Other cycles may have existed and probably did exist, but too briefly for permanent record. Six of these nine cycles are thought to belong to post-Cretaceous time and three to Cretaceous time.

The question of the subaerial or marine origin of these peneplains is debated, but decisive criteria are lacking for a final pronouncement.

¹ Published by permission of the Director of the United States Geological Survey. The writer takes pleasure in acknowledging her indebtedness to M. R. Campbell and G. W. Stose of the United States Geological Survey for helpful comments and queries made on the subject-matter of this paper, and to Professor W. M. Davis for valuable specific suggestions.

In any investigation of the cycles of erosion, complete or incomplete, that collectively constitute the erosion history of the Piedmont province of the Appalachian highlands, the stratigraphic record preserved on the margin of the province must furnish the data by which the succession and age of such erosion cycles stand or fall.

That aerial and marine erosion has taken place ever since continental plateaus and oceanic basins came into existence is unquestioned: only such interaction of air, water, and land masses is conceivable. The character and rapidity of erosion will be controlled by altitude, rock, and climate, but the duration of an erosion period will be dependent upon the stability of the strand line: a long period of quiescence will permit prolonged aerial and marine erosion with reference to a given base-level, and a period of uplift will interrupt and renew erosion with reference to a new base-level. The evidence of such movements of the strand line inaugurating erosion is furnished by the stratigraphic register.

In the Piedmont province of Pennsylvania with the beginning of Cretaceous sedimentation the stratigraphic record seems to indicate a succession of such erosional conditions maintained by an alternation of periods of continental quiescence with periods of movement. That these periods of stability have been of different durations is an obvious deduction from the sedimentary record.

The stratigraphic record on the Atlantic plain which is the submerged margin of the Piedmont province is as follows:

Recent deposits	
Unconformity	
Pleistocene deposits	
Talbot (Cape May): clay, sand, and gravel	30 feet
Unconformity	
Wicomico (Pensauken): clay, sand, and gravel	25 feet
Unconformity	
Sunderland (Bridgeton): clay, sand, and gravel	25 feet
Unconformity	
Late Brandywine: sand and gravel	1± foot
Pleistocene (or Late Tertiary?) deposits	
Unconformity?	
Early Brandywine: sand and gravel	50 feet

Miocene deposits	
Unconformity	
St. Mary's: sand and clay.....	280 feet
Choptank: sand, clay, and marl.....	175 feet
Unconformity	
Calvert: sand and clay.....	310 feet
Unconformity	
Eocene deposits	
Nanjemoy: sand.....	125 feet
Aquia: greensand.....	100 feet
Unconformity	
Upper Cretaceous (Cretaceous) deposits	
Manasquan: clay and sand.....	50 feet
Rancocas: greensand.....	80 feet
Monmouth: sand.....	100 feet
Unconformity	
Matawan: micaceous sandy clay.....	70 feet
Unconformity	
Magothy: sand and clay.....	100 feet
Unconformity	
Raritan: clay and sand.....	350 feet
Unconformity	
Lower Cretaceous (Comanchean) deposits	
Arundel: clay and sand.....	125 feet
Unconformity	
Patapsco: clay and sand.....	200 feet
Unconformity	
Patuxent: sand and arkose.....	350 feet
Unconformity	
Crystalline formations	

With the Cretaceous, Tertiary, and Pleistocene registration of continental movements before us, it is no longer possible to believe that the erosion history of this region is told in two cycles of erosion, producing two peneplains: the Kittatinny,¹ or Schooley, of Cretaceous age, and the Shenandoah, or Somerville,² of Tertiary age. That there is topographic evidence of more than two erosion

¹ Bailey Willis, "The Northern Appalachians," *Nat. Geog. Mon.*, 1895, pp. 169-202. C. W. Hayes, "The Southern Appalachians," *Nat. Geog. Mon.*, 1895, pp. 305-36. C. W. Hayes and M. R. Campbell, "Geomorphology of the Southern Appalachians," *Nat. Geog. Mon.*, 1894, pp. 63-126.

² W. M. Davis and J. W. Wood, Jr., "The Geographic Development of Northern New Jersey," *Proc. Bost. Soc. of Nat. Hist.*, Vol. XXIV (1889), pp. 365-423.

periods in the Appalachian highlands has been recognized by Keith,¹ Campbell,² and others.

In the sedimentary sequence of the Atlantic plain there are ten significant unconformities—that is, ten intervals of erosion alternating with intervals of deposition. Not all of the deposits are known to be marine, so that ten submergences cannot be postulated. There are six less significant unconformities.

The time represented by the deposits and unconformities has been estimated at 56,500,000 years.³ There could not conceivably be conditions more favorable for a succession of erosion cycles falling so far short of completion as to leave permanent traces of the sequence, nor a stratigraphic record more compelling for the acceptance of such traces as evidences of erosion cycles. It is not probable that traces are preserved of every incomplete erosion cycle.

The topography of erosion cycles early interrupted would be obliterated by subsequent erosion cycles of longer duration. Small beginnings, if they existed, might be quite similar to the three most recent terraces, which are being modified and will in time be completely obliterated by subsequent erosion.

Such incomplete, obliterated cycles may be registered only in the lesser unconformities of the stratigraphic record, which is easily more complete than the topographic record. Did the geologist base his expectations on stratigraphy alone, he would look for a series of more or less discontinuous and more or less warped benches or terraces facing the sea, or, in the case of the lower terraces, following inland the river valleys, and not perfectly stairlike because each terrace will have its peculiar angle of slope. The terraces are the topographic record of the succession of interrupted erosion cycles of which the unconformities in the stratigraphic sequence are the geologic record.

¹ Arthur Keith, "Some Stages of Appalachian Erosion," *Bulletin Geol. Soc. America*, Vol. VII (1896), pp. 519-24. "Geology of the Catoctin Belt," *Fourteenth Annual Report, U.S. Geol. Sur.*, Part II (1892-93), pp. 285-395.

² M. R. Campbell, "Geographic Development of Northern Pennsylvania and Southern New York," *Bulletin Geol. Soc. America*, Vol. XIV (1903), pp. 277-96.

³ Joseph Barrell, "Rhythms and the Measurement of Geologic Time," *Bulletin Geol. Soc. America*, Vol. XXVIII (1917), pp. 745-904.

Nature is less obvious and more complex in her methods and evidences than such expectations would imply, but a detailed and careful study of approximately level tracts and benches seems to justify the following series of peneplains and terraces related to the major unconformities of the stratigraphic record.

Name	Altitude West	Altitude East	Sediments	Age	Preserved
<i>Peneplains</i>					
Kittatinny.....	1800-1600-1100		Patuxent.	Jurassic and Lower Cretaceous	Quartzite
Schooley.....	1300-1000-900		Patapsco-Arundel.	Lower Cretaceous	Granite
Honeybrook....	860-800-700		Raritan-Manasquan.	Upper Cretaceous	Granite
Harrisburg.....	800-500		Aquia-St. Mary's.	Tertiary	Shale
Early Brandywine....	500-400-390		Early Brandywine.	Pliocene (Pleistocene)	Shale, etc.
<i>Terraces</i>					
Late Brandywine ...	400-300-200		Late Brandywine.	Pleistocene	Mica gneisses
Sunderland....	300-180-100		Sunderland.	Pleistocene	Mica gneisses
Wicomico.....	90-45		Wicomico.	Pleistocene	Mica gneisses
Talbot.....	45-40-0		Talbot.	Pleistocene	Mica gneisses

The oldest peneplain, the highest inland from the sea and the lowest near the sea where it is preserved under sedimentary rocks, is the *Kittatinny*. This peneplain surface is so strikingly upheld,

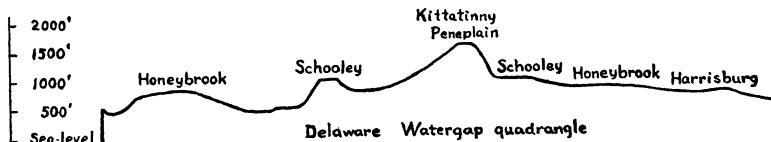


FIG. 1.—Section across Godfrey Ridge and Kittatinny Range, at the Delaware Water Gap, Delaware Water Gap quadrangle, Pennsylvania-New Jersey.

although not preserved unmodified, by the indurated sandstone of Kittatinny Mountain (1,600 feet), its type locality (see Fig. 1), and in other resistant ridges of the Appalachian highlands that it was early recognized and an effort was made to fit it to the lower summits of Schooley Mountain and still lower surfaces in the

Piedmont province. In order to secure continuity between adjacent and discordant levels, it was necessary to assume abrupt and steep warping of the peneplain in some localities, and when accordance was secured it left unexplained the remarkable preservation throughout the Piedmont province of so ancient an erosion surface, and failed to explain why no records were preserved of the later continental movements and erosion cycles which are recorded in the sedimentary succession.



FIG. 2.—Kittatinny, Schooley, and Honeybrook peneplains in the Reading quadrangle. The summit of the ridge on the left at 1,140 feet represents the Kittatinny; the ridge in the middle at 1,000 feet, the Schooley; the ridge on the right at 700 feet, the Honeybrook peneplain. West Reading in middle distance, looking east.

The Kittatinny peneplain has been traced northeastward from the type locality to the base of the Catskill Mountains in New York, and westward and southward into Maryland and West Virginia. In the Blue Ridge province, surfaces which are probably remnants of the Kittatinny have altitudes of 1,800 feet in southern Pennsylvania (South Mountain), 1,300 on Blue Mountain to the northeast, and 1,200 feet in the quartzite ridge east of Reading (Penn Mountain, the dominating highland of the area, designated the Reading Prong of the New England upland). (See Figs. 2 and 3.)

Whether the Kittatinny peneplain is anywhere preserved in the Piedmont province of Pennsylvania is questionable. Reduced remnants of it may appear on Welsh Mountain (Honeybrook

quadrangle), a quartzite ridge, but, as is to be expected in a region so near the sea, erosion in subsequent cycles has probably modified the Kittatinny surface, notwithstanding the resistant character of the rock.

Near the "fall-line" where the lowest and oldest formations (Patuxent formation) of the coastal plain lie directly upon a peneplained surface of crystalline rocks, the floor which bears them may be that part of the Kittatinny peneplain which was submerged, was buried beneath sediments, and was thus preserved without modification while far inland the peneplain was still developing.



FIG. 3.—Schooley peneplain in the Reading quadrangle. The summit of Irish Mountain in the distance at 1,000 feet represents the Schooley peneplain, as seen from a point on the Early Brandywine peneplain, two miles east of Shoemakersville, looking south 45° east.

The Patuxent formation once overlapped the margin of the Piedmont province to a distance inland considerably greater than is now covered by it; but wherever it has been removed by erosion, the surface of the peneplain has been attacked so that the old surface cannot be found except perhaps in the immediate vicinity of the remnants of the formation. This surface lies at about 180 feet above sea-level, rising in Maryland to 280 feet. This first peneplain, carved on a dissected highland or possibly on uplifted peneplains, obliterated in this region all pre-existing erosion surfaces except those that were protected by a cover: an example of such a surface is to be found on Paleozoic rocks, where they are covered by Triassic formations (see Fig. 4). The later peneplains, carved on uplifted peneplains or terraces, never completely obliterated pre-existing erosion surfaces.

That the Kittatinny erosion cycle exceeded in duration any of the subsequent cycles must have been the case not alone because no subsequent cycle has been coextensive with it, but also because no subsequent cycle has succeeded in wearing down the most resistant rocks leveled by Kittatinny erosion and located well within the area of subsequent peneplanation.

The next oldest peneplain, the Schooley, with its type locality the granite summits of Schooley Mountain (1,300 feet), New Jersey, has been traced northward to the Mohawk Valley, westward to

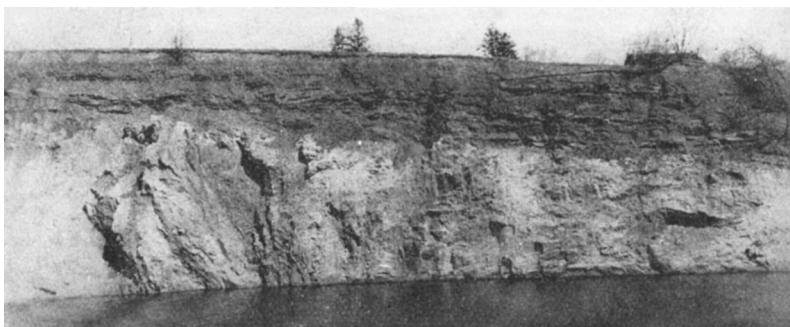


FIG. 4.—Section of erosion surface on the Paleozoic, protected by a cover of Triassic rocks. Port Kennedy, Montgomery County, Pennsylvania.

Syracuse,¹ and southward to the Potomac.² In western New York it appears to coalesce with the Kittatinny, suggesting that in that region there was no uplift separating the two erosion periods.

At the Delaware Water Gap³ the ridge between Godfrey Ridge and Kittatinny Range with summit areas at 1,000 feet may represent the Schooley peneplain, and Wind Gap between Blue Mountain and Kittatinny Mountain in Northampton County at the same elevation may have been a water gap during the early part of the Schooley erosion cycle. In the Blue Ridge province remnants are preserved in summit areas of 1,200 and 1,000 feet

¹ Memorandum by M. R. Campbell.

² Mem. by the writer.

³ G. W. Stose, "Text of Delaware Water Gap Sheet," *U.S. Geol. Survey*.

altitudes. East and northeast of Reading there are many flat-topped granite and quartzite hills rising to a height of 1,000 feet, the Schooley level in that locality (see Figs. 5-10). On one of these, the Schooley remnant is separated from the adjacent Kittatinny



FIG. 5.—Schooley peneplain above the Honeybrook peneplain in the Boyertown quadrangle. The summit of Long Hill in the distance at 1,040 feet represents the Schooley peneplain, as seen from a point one-half mile southeast of Shanesville, looking south. The summit of the ridge in the foreground is a remnant of the Honeybrook peneplain.



FIG. 6.—Schooley peneplain in the Reading quadrangle. The higher parts of the past-maturely dissected upland one and one-half miles southeast of Fleetwood represent the Schooley peneplain at an altitude of 940-1,000 feet. Hill road, looking south on hills south of Princeton.

remnant by a steep slope (Fig. 9). In the central Piedmont province the Schooley peneplain descends to an altitude of 800 feet (Coatesville quadrangle). If the Schooley peneplain reappears near the "fall-line," it is found on the border of, and passing

beneath, the Patapsco formation, which rests upon eroded Patuxent, at an altitude of 100 feet, rising to 130 feet in Maryland. The next movement of uplift not only raised the Schooley peneplain



FIG. 7.—Schooley, Honeybrook, and Late Brandywine peneplains in the Boyertown quadrangle. High hills in the background are remnants of the Schooley peneplain, altitude 1,000 feet; hill in center in middle distance is at the level (660 feet) of the Honeybrook peneplain; and the foreground is on the Late Brandywine peneplain, altitude 420 feet. Looking west from Palm Station.



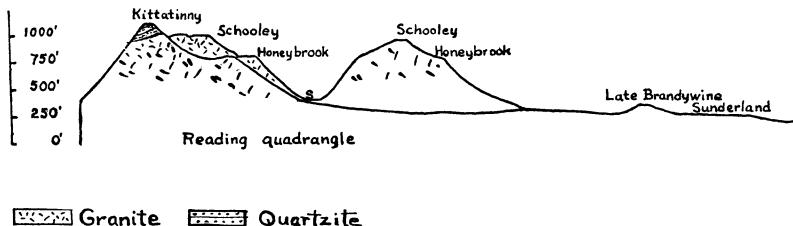
FIG. 8.—Schooley and Honeybrook peneplains in the Boyertown quadrangles. Hills in the background are remnants of the Schooley peneplain, altitude 1,000 feet; foreground on the Honeybrook peneplain, altitude 800 feet. Devil's Hump, looking south 30° west.

and remnants of the Kittatinny peneplain to a considerable height, but warped them.¹

The next younger peneplain, the Honeybrook, appears in Godfrey Ridge, northwest of Kittatinny Mountain, at the Delaware

¹ Bailey Willis, *op. cit.*, pp. 189-90. C. W. Hayes, *op. cit.*, p. 330.

Water Gap, and on the hill summits southeast of Kittatinny Mountain at an altitude of 800 feet. This altitude is a very persistent one in the Appalachian Valley from this region to Susquehanna River. The Hamburg and Slatington quadrangles show the Honeybrook peneplain dominating the interstream areas. It retains an altitude of 800 feet in the Blue Ridge province and is well shown east of Reading, where Neversink Mountain, Guldin Hill, and the southeastern spur of Penn Mountain preserve its surface (see Fig. 9). The Honeybrook and the Schooley are here



■■■ Granite ■■■ Quartzite

FIG. 9.—Section across Penn Mountain and Guldin Hill, showing remnants of the Kittatinny, Schooley, and Honeybrook peneplains, and of the Late Brandywine and Sunderland erosion surfaces. Reading Prong of the New England upland, Reading quadrangle, Pennsylvania.

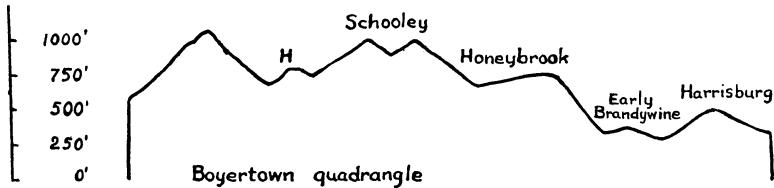


FIG. 10.—Section across Long Hill, Devil's Hump, and Gabel Hill, showing the Schooley, Honeybrook, and Harrisburg peneplains. Boyertown quadrangle, Pennsylvania.

found adjacent, are both cut in granite, and are separated by a steep slope (see also Figs. 11 and 12).

In the Piedmont province the Honeybrook descends to 700 feet. On the divide between Susquehanna and Schuylkill rivers the North and South Chester Valley Hills preserve this peneplain. The most extended remnant of it is found on the granite about Honeybrook, 16 miles south of Reading, and from this type locality

the peneplain is here named the Honeybrook.¹ It is not claimed that this plain has been traced throughout the Appalachian highlands division, but in the Piedmont province of Pennsylvania it



FIG. 11.—Honeybrook peneplain below the Schooley, Boyertown quadrangle. The upland in the distance represents the Schooley peneplain, altitude 1,000 feet, and that in the middle distance, altitude 800 feet, the Honeybrook peneplain, as seen from a point one-fourth mile southwest of Shanesville, looking north 15° west.



FIG. 12.—Water gap in a ridge whose summit is a remnant of the Honeybrook peneplain, Boyertown quadrangle. Upland in background, altitude 1,000 feet, represents the Schooley peneplain. Summit of ridge 800 feet and stream in the water gap, 440 feet. View from a point one-fourth mile southwest of Shanesville, looking north 45° west.

seems to represent a distinct erosion level between the Schooley and Harrisburg. The Honeybrook peneplain has been completely

¹ The Schooley peneplain was traced from Pennsylvania to the Potomac Valley in Maryland to surfaces (Green Ridges) which have been ascribed to the Weverton peneplain (*Maryland Geol. Survey*, Vol. VI [1906], pp. 87-88). Elsewhere in the central Piedmont of Pennsylvania the Weverton as defined corresponds to a lower peneplain than the Schooley. A new name has therefore been introduced for a redefined Weverton.

removed at the "fall-line." It passes under the Raritan (Upper Cretaceous) formation near the junction of the Coastal Plain and Piedmont.



FIG. 13.—Harrisburg peneplain in the Coatesville quadrangle. The dissected peneplain at an altitude of 600 feet, as seen one-third of a mile northwest of Humphreyville, looking southwest.

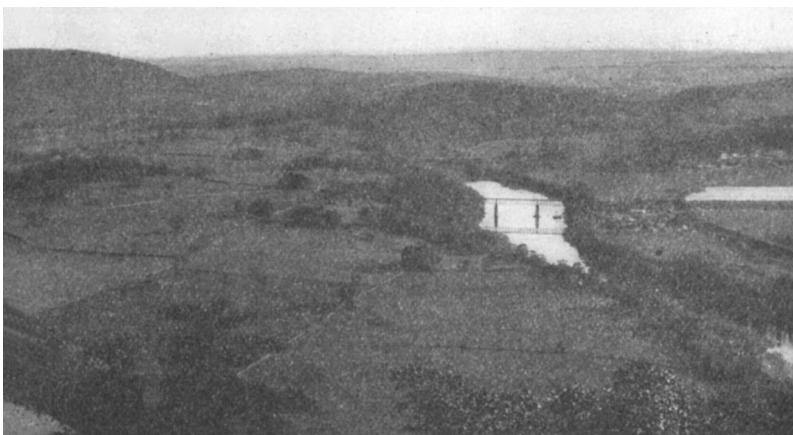


FIG. 14.—Harrisburg peneplain on Schuylkill River, in the Reading and Honeybrook quadrangles. The summit of the hill in the middle distance in which the river is cutting a steep bluff represents the Harrisburg peneplain, altitude 600-660 feet. Gibraltar Hill, 900 feet, a monadnock, on the left, and the Sunderland plain in the foreground, as seen from Lookout Point, Neversink Mountain, looking south.

The Harrisburg peneplain¹ has been restricted, with the approval of its sponsor, at its type locality northeast of Harrisburg to upland

¹ M. R. Campbell, *Bulletin Geol. Soc. America*, Vol. XIV (1903), pp. 277-96.

surfaces on the Ordovician (Martinsburg) shale which reach 600 feet, and to corresponding altitudes on Delaware and Potomac rivers (see Figs. 13 and 14). At this altitude it is widespread in



FIG. 15.—Honeybrook and Harrisburg peneplains in the Boyertown quadrangle. The Honeybrook peneplain corresponds with the surface of the upland on the left at an altitude of 800 feet and the Harrisburg with the upland in the distance on the right at an altitude of 600 feet, as seen from the northeast end of Long Hill, looking north 55° east.



FIG. 16.—Remnants of Early Brandywine and Harrisburg peneplains in the Harrisburg quadrangles. The surface of the upland represents the Early Brandywine peneplain upon which the hills, rising to an altitude of 740 feet and perhaps to the level of the Harrisburg peneplain, stand as monadnocks. The view is from a point on the Sunderland level one-half mile northwest of Maiden Creek, looking southwest.

the central Piedmont province and descends on the border of the upland to 500 feet (North and South Chester Valley Hills in the Schuylkill Valley). The Harrisburg does not appear in the "fall-line" zone, but probably descends below sea-level beneath the

Aquia Greensands (Tertiary), which lie far out on the Coastal Plain.

The Early Brandywine, the youngest and most widely preserved of the five peneplains, is found on Ordovician shale at the 500-foot level, northeast of Harrisburg. It contains at this altitude in the



FIG. 17.—Early Brandywine peneplain in the Boyertown quadrangle. The peneplain corresponding with the surface of the upland in the distance at an altitude of 560 feet is seen from a point one-half mile west of Eschbach, looking south 45° east.

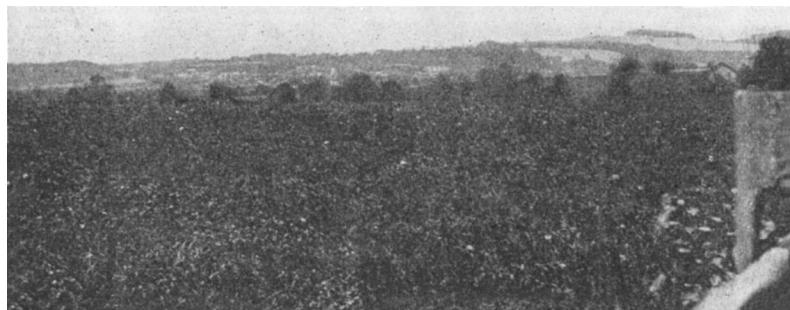


FIG. 18.—Early Brandywine peneplain in the Reading quadrangle. The peneplain at an altitude of 500 feet is represented by the surface of the upland in the distance, as seen from a point on the Sunderland level one-half mile northwest of Maiden Creek, looking south 65° west toward Leesport.

valley of the Delaware at the Water Gap and in the Schuylkill and Potomac valleys (Antietam quadrangle). It ranges from 400 to 450 feet in the Piedmont upland of Pennsylvania where, as is to be expected, because it is the most recently formed peneplain, it is the most pronounced upland level (see Figs. 15-18).

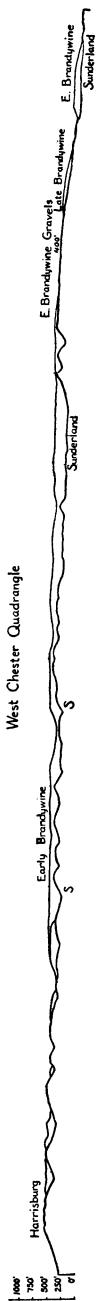
West Chester is located upon this peneplain surface, which is the dominant altitude throughout the West Chester quadrangle (see Figs. 19 and 20). At 400 feet it carries Early Brandywine gravel and sand, 10 miles west of the "fall-line" zone. It has been named the Early Brandywine from the formation which is found at this altitude and on the seaward continuation of the slope. This peneplain is correlated with the so-called Lafayette¹ terrace recognized in Maryland² but a more widespread extension is claimed for the Early Brandywine peneplain.

The Early Brandywine peneplain is everywhere submaturely dissected. The summits of the inter-stream areas preserve the peneplain, gentle slopes from these summit remnants lead to the gorges (Pleistocene) of the main streams and of the larger tributaries or form the U-shaped valleys of head-water streams. These slopes have an elevation inland from 300 to 400 feet and in the "fall-line" zone from 200 to 300 feet (see Figs. 21-25).

Following the deposition of the Early Brandywine formation and before the deposition of the Sunderland formation, the whole continental shelf was brought above the sea and master-streams of the Atlantic plain were extended to the edge of the continental shelf. To this period, which may have been well within Pleistocene time, is attributed the formation of the Late Brandywine benches and slopes. Few formations can be correlated with it, as the

¹ Owing to the change of the name Lafayette to Brandywine, the more recent name has been given to the peneplain. The name Brandywine is taken from a village of that name in Prince George County, Md., where the formation is reported to be characteristically developed. The position and level of the gravel of this type locality at 233 feet seem to indicate that it is the low-level Brandywine or Late Brandywine gravel as it is provisionally named in this paper.

² *Maryland Geol. Survey*, Vol. VI (1906), pp. 59-60.



marine sedimentation of the period took place, mainly at least, beyond the continental shelf. Gravel, which has been included in the "Brandywine" (Early and Late Brandywine), but which lies at all places at a lower level than the Early Brandywine gravel, is thought to be a terrestrial deposit of Pleistocene streams. Such gravel is found on the Chester quadrangle at an altitude of 300 feet and on Elk Neck, Elkton quadrangle, between 200 and 300 feet.

The records of this period of erosion are the dissection of the Early Brandywine peneplain, producing the stream terraces and



FIG. 20.—Section in Norristown quadrangle

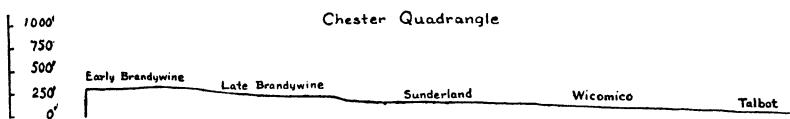


FIG. 21.—Section in Chester quadrangle

the slopes which separate the Early Brandywine peneplain and the Sunderland terrace, and the submerged valleys on the continental shelf. Late Brandywine slopes are well defined on the Chester quadrangle, and furnish a commanding site for the buildings of Swarthmore College.

The Sunderland, Wicomico, and Talbot terraces have been recognized and defined in Maryland.¹ In Pennsylvania a scarp separates the Late Brandywine and the Sunderland. This scarp, which the central building of Swarthmore College fronts, represents either the old estuarine shore cliff or the escarpment of the wide meander belt of Delaware River.

Erosion truncated the Late Brandywine slopes and dissected them and the Early Brandywine peneplain along drainage ways. What has been called the Somerville peneplain seems to the writer

¹ *Maryland Geol. Survey*, Vol. VI (1906), pp. 61-67.

to be such an inland extension of erosion during the Sunderland cycle.

In general the Sunderland extends from the 100 to the 180 contour lines: the Wicomico from the 80 to the 90 contour lines, and the Talbot, where it does not coalesce with the Wicomico, from the 40-foot contour to sea-level. These three terraces are conspicuously developed in eastern Pennsylvania parallel to Delaware River. In Maryland the Wicomico and Talbot terraces are in some places obliterated and the Sunderland reaches the edge of the beach with a cliff 100 feet high, but this is not the case in Pennsylvania where the terraces are not seacoast features.

The Wicomico terrace wraps about the Sunderland as the Sunderland does about the Late Brandywine, with usually a well-marked break between the two, except in the gorges of the tributary streams. The Talbot terrace borders the Wicomico, which it penetrates along drainage ways, and in some places parallel to Delaware River coalesces with the Wicomico.

It has not proved practicable to show by graphic means the distribution of the remnants of the peneplains and terraces in the Piedmont province of Pennsylvania. It may be stated that in general the oldest peneplain is farthest inland and the youngest nearest the shore, with those of intermediate age ranging between. If this region had been one of uniform resistance to weathering, there would have been a perfect operation of this law of areal

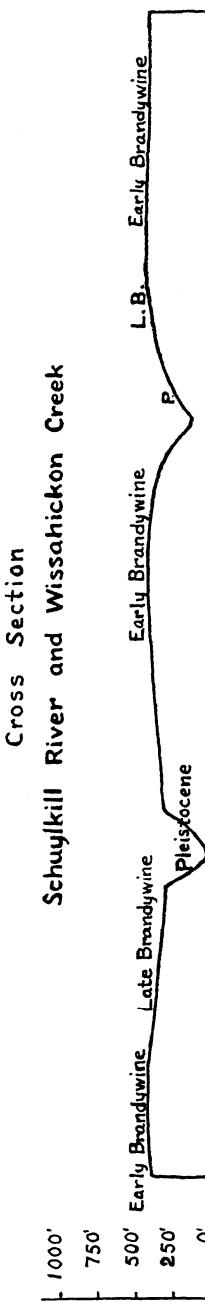


FIG. 22.—Section crossing Schuylkill River and Wissahickon Creek

distribution: the areal succession of peneplains from interior to coast would exactly accord with the chronological succession. The region is, however, one of varied structural and lithologic resistance to weathering and the peneplains are not therefore so simply spaced; younger peneplains on relatively weak rocks are found inland at higher altitudes than the marginal remnants of older peneplains. This fact would be still more apparent if the extreme margins of the older peneplains, now buried beneath sedimentary formations, were shown.

The question of the origin of these peneplains, that is, of the nature of the dominant erosive agent, is open to debate. The

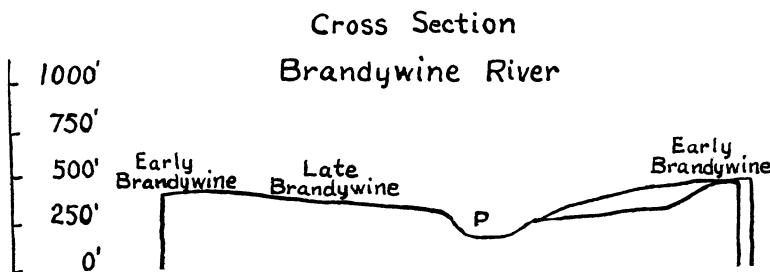


FIG. 23.—Section crossing Brandywine River

three youngest terraces, in Maryland presumably of marine origin, are in this region of fluvial-estuarine or of fluvial origin; that is, they were developed on the borders of the Delaware estuary or on a shrinking meander belt of Delaware River.

That the Late Brandywine is of subaerial origin is concluded from the evidence of the valleys, now submerged, which extend across the continental shelf and which it is believed were excavated in Late Brandywine time.

That the five peneplains are in part of marine and in part of subaerial origin seems a warranted conclusion. Each peneplain was partly submerged and carries marine sediments, but there does not seem to be sufficient proof that any one peneplain was completely submerged. They parallel the coast line as would be the case were they of marine origin, but this may also be true of subaerial peneplains, and the great inland extension of the Kittatinny

and Schooley peneplains with an indefinite thin margin is indicative of subaerial erosion. The contact of the Honeybrook and Schooley peneplains, on the Reading quadrangle, on the other hand, suggests



FIG. 24.—Late Brandywine peneplain in the Reading quadrangle. The peneplain at an altitude of 400 feet, as seen from the hillside south of Oley Furnace, looking south toward Friedensburg.



FIG. 25.—Honeybrook and Late Brandywine peneplains in the Reading and Boyertown quadrangles. The surface of the upland in the distance at an altitude of 800 feet represents the Honeybrook peneplain, and the level land in the middle distance at altitudes ranging from 400 to 440 feet, the Late Brandywine peneplain, as seen from a point one-fourth miles southwest of Oley Furnace, looking south 45° east toward Shenkel Hill.

a sea cliff. In the case of the Harrisburg and Early Brandywine peneplains definite proof of subaerial or marine origin has not been found.